Are charge fluctuations a good signal for QGP?

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Abstract

A recent proposal to study charge fluctuations as a possible signal of quark - gluon plasma is discussed. It is shown that the "pion gas model" considered as the reference sample is unrealistic and the expected signal from plasma may be difficult to distinguish from that coming from "standard collisions".

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In a recent paper Jeon and Koch [1] argued that the event-by-event fluctuations of charge (or, equivalently, of the ratio of positive to negative pions) in a restricted rapidity range may be used as a tool to signal the possible formation of quark - gluon plasma (QGP). They compare the ratio of charge dispersion squared to the charged multiplicity in two models: the "pion gas" and QGP and conclude that they differ by a factor of five. Similar result is found for the dispersion of "positive-to-negative" ratio for pions. The dramatic difference may be easily understood as the reflection of small quark charges as compared to hadrons and of zero gluon charges.

The Authors conclude that the strong decrease of charge fluctuations in the QGP as compared to a pion gas should be seen as an "unmistakable signal of QGP formation from 'Day-1' measurements" at RHIC. They add later some caveat about resonances and other correlation effects which may reduce the fluctuations in the "pion phase", but these are claimed to be minor corrections.

However, the value of ratio $D_Q^2/ < n_{ch} >$ obtained in the pion gas model seems to be unrealistic. In the past charge fluctuations were measured in hadron collisions, usually for separated CM hemispheres [2]. The values of D_Q^2 were systematically much lower than $< n_{ch} >$; semi-inclusive data indicated that charge dispersion squared is indeed proportional to charged multiplicity, but the proportionality coefficient is below 0.5.

For the energy and rapidity range similar to that considered in [1] (and expected at RHIC) a reliable estimate is available from the JETSET/PYTHIA generator [3] for *pp* collisions. We performed such calculations at CM energy of 180 GeV and 1800 GeV for centrally located bins of rapidity of width 2, 4, 6 and 8. The results for the ratio $D_Q^2/ < n_{ch} >$ as a function of a bin width are shown in Fig.1.

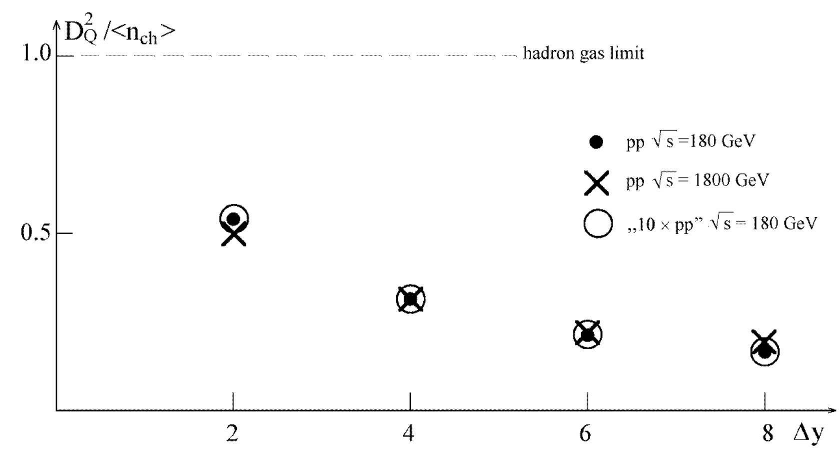

Figure 1: *The values of the ratio $D_Q^2/ < n_{ch} >$ from the PYTHIA/JETSET generator for pp collisions at 180 GeV (dots) and the 1800 GeV (crosses) vs half bin width in rapidity. The values for "heavy ion events" formed from groups of ten pp events at 180 GeV are shown as open circles.*

One sees a fast decrease with the bin width; the values are changing between 0.5 and 0.15. This reflects the approximate ordering of charges (with alternating signs) along a fragmenting string in the model; charge dispersion squared increases much slower than average multiplicity, and for wide bins it is bound in fact to decrease towards a limiting value of zero (when all the phase-space is covered). The energy dependence is very weak. This is also not surprising: for the central region in the PYTHIA generator increasing energy results just in the growing number of contributing strings. This increases in very similar way both the numerator and denominator of the ratio.

Obviously, we need an estimate for heavy ion collisions and not for hadron scattering. However, since our aim is to contrast the QGP signal with "standard" collisions, it should be instructive to superimpose many *pp* collisions to mimick a heavy ion interaction. We have done it using the momenta from groups of ten *pp* events to form single "events". The ratio $D_Q^2/ < n_{ch} >$ resulting from this simulation is also shown in Fig.1. As expected, the points are indistinguishable from those for *pp* collisions: both numerator and denominator of the ratio are simply multiplied by the number of superimposed events, leaving the value of the ratio unchanged.

We see that the value of the investigated ratio for hadron collisions in a realistic model without QGP is much smaller than 1 and similar results are expected for heavy ion collisions, if describing them as superposition of independent nucleon-nucleon collisions is a reasonable approximation. Moreover, the value depends quite strongly on the chosen range of rapidity. It may be easily as low as the prediction from QGP. Thus a measurement of this ratio at RHIC is not likely to prove or disprove the formation of QGP. Obviously, for more precise calculations of the "reference values without QGP" one should use the generators dedicated for heavy ion collisions (as FRITIOF or VENUS). However, we do not see any reasons why they should give results different from ours.

Summarizing, we have shown that the predictions for the ratio $D_Q^2/ < n_{ch} >$ from the "pion gas model" used in [1] as reference for the possible signal of QGP are not reliable. The realistic estimates are much lower, which seems to diminish the value of this quantity as a sensitive indicator of the QGP formation.

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